

Title page

**Association of decreased hemoglobin levels with worse muscle mass and strength in
community-dwelling older people**

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Abstract

We investigated the associations between red blood cell (RBC) count, hemoglobin (Hb) levels, muscle properties, and muscle strength in community-dwelling older adults, and examined whether RBC count and Hb levels were linked to muscle strength through muscle mass and/or quality, and whether these relationships were influenced by physical activity. The study included 85 community-dwelling older adults (39 males; mean age 75.3 ± 6.7). The participants visited the laboratory in the morning for venous blood sampling to analyze blood biomarkers. Quadriceps femoris muscle thickness (MT, muscle mass index) and echo intensity (EI, muscle quality index) were measured via B-mode ultrasonography, and maximum isometric knee extension strength was assessed using a dynamometer. The average daily step count was recorded for 2 weeks as an index of physical activity. Correlation and mediation analyses were used to investigate the associations between blood biomarkers and muscle properties, strength, and physical activity. The RBC count and Hb levels were positively correlated with MT and muscle strength, and negatively correlated with EI. After adjusting for age and sex, the correlations between RBC count, Hb levels, and MT and muscle strength remained significant, whereas the associations with EI disappeared. In the mediation analyses, the direct effect of RBC count and Hb levels on muscle strength was not significant, whereas the indirect effect of MT was, regardless of whether physical activity was adjusted. In community-dwelling older adults, lower RBC counts and Hb levels appear to be associated with diminished muscle mass, potentially resulting in muscle weakness.

Key Words: community-dwelling older adults, hemoglobin levels, muscle mass, muscle quality, muscle weakness

Introduction

Aging is accompanied by changes in various organ functions and a decrease in physiological reserve capacity, a decline commonly known as frailty, which increases the susceptibility to health problems (Veronese et al. 2021). Decreased red blood cell (RBC) count and hemoglobin (Hb) levels are common examples of reduced physiological reserve capacity (Picca et al. 2022; Pires Corona et al. 2015). As age increases, Hb levels tend to decrease (Su et al. 2023). Anemia is defined as an Hb level below a specific threshold of < 13 g/dL for males and < 12 g/dL for females (World Health Organization. 1972; Lopez et al. 2016). Anemia has been reported to be associated with decreased physical function, increased risk of falls, decreased cognitive function (Artz 2008; Denny et al. 2006), and higher mortality (Culleton et al. 2006).

In clinical populations, decreases in RBC count and Hb levels may be associated with worsening muscle properties (e.g., muscle mass and muscle quality) and strength. In patients with hematological malignancies, muscle strength is significantly reduced in those with lower Hb levels than in those with higher Hb levels (Fukushima et al. 2019). In kidney transplant recipients, Hb levels have been shown to be independently associated with reduced muscle mass and strength (Vinke et al. 2022). Additionally, Hb levels have been reported to be helpful in the diagnosis of sarcopenia and serve as useful screening indicators of muscle strength and walking speed, both of which are key diagnostic criteria for sarcopenia (Tseng et al. 2021). However, these associations were observed in patient populations where the progression of disease or disability may simultaneously contribute to both a decline in Hb levels and muscle degeneration.

Previous studies in community-dwelling older adults have reported that Hb levels are

associated with muscle mass and muscle quality, which reflect the proportion of non-contractile elements in the muscle, but not with muscle strength (Cesari et al. 2004). Moreover, Hammer et al. (2024) found a significant association between Hb levels and muscle strength only in women < 80 years old, but not in women $\geq$ 80 years old or in older men. These community-based findings contrast with results from clinical populations, where lower RBC counts or Hb levels have been associated with reduced muscle strength (Fukushima et al. 2019; Tseng et al. 2021; Vinke et al. 2022). Although previous studies have demonstrated associations between RBC counts or Hb levels and muscle properties, muscle strength, or physical performance (Cesari et al. 2004; Corona et al. 2022; Hammer et al. 2024; Liu et al. 2023), their findings remain inconsistent. Furthermore, given the established relationship between muscle properties and strength (Fukumoto et al. 2012), no study has comprehensively evaluated the interplay among hematological measures, muscle properties, and strength. Consequently, the extent to which these variables are interrelated in populations with typical physical activity levels and minimal confounding factors remains unclear.

In this study, we aim to investigate the relationships between RBC count, Hb levels, and muscle properties, and muscle strength in community-dwelling older people, and whether the relationship among these variables are influenced by physical activity. We hypothesized that in community-dwelling older people, the decrease in RBC count and Hb levels are related to worse muscle properties, and the decrease in RBC count and Hb levels are associated with muscle weakness through muscle properties, and that this relationship is not affected by physical activity.

Methods

Participants

From April to September 2019, we recruited older adults (> 60 years of age) living in the community. All participants were recruited based on a physical fitness test conducted in Kyoto city (Fukumoto et al. 2022). Participants who met the following criteria were included in the study: 1) ability to perform activities of daily living independently and walk without assistive devices, and 2) no current use of medications that could potentially affect blood or musculoskeletal functions. Participants with the following conditions were excluded: 1) any cardiovascular disease (e.g., angina pectoris, myocardial infarction, or heart failure); 2) hematological disorders, including a history of clinically diagnosed anemia or newly identified severe anemia (Hb < 8 g/dL) during study blood sampling; and 3) diseases affecting daily life or muscle strength measurement, such as severe musculoskeletal disorders, neuromuscular disorders, or significant pain. Participants were thoroughly briefed on the study's procedures, objectives, and potential risks. After receiving comprehensive information, the participants provided written informed consent. The experimental protocols were approved by the Ethics Committee of Kyoto University (ethics approval number: R1746).

Procedures

The participants were instructed to avoid excessive physical activity before the measurements. Upon arrival at the laboratory, venous blood sample collection, muscle property measurements, and muscle strength measurements were performed. On the second day after the measurement, the step counter was worn for 2 weeks.

Blood biomarker examination

Participants were instructed to fast after their evening meal the day before the test, and 25 mL venous blood was collected from the antecubital vein the following morning into EDTA-containing tubes. The blood parameters analyzed included RBC count, white blood cell (WBC) count, platelet (PLT) count, and Hb levels, using an automated hematology analyzer (XN-9000, Sysmex Corporation, Kobe, Japan). RBC counts were measured using the sheath-flow direct-current detection method, WBC counts were determined by fluorescence flow cytometry in the WNR/WDF channels with a semiconductor laser and hydrodynamic focusing, PLT counts were assessed using the fluorescence platelet channel, and Hb levels were measured using the sodium lauryl sulfate hemoglobin method. All parameters were analyzed as continuous variables to capture inter-individual variation.

Muscle properties measurements

To prevent the influence of fluid flow, the participants were instructed to lie on the treatment bed for 5 min. B-mode ultrasonography (LOGIQ e, GE Healthcare, Buckinghamshire, United Kingdom) with an 8–12 MHz linear-array probe was used to measure the muscle characteristics. Ultrasound measurements were performed on the right leg. Images of the vastus lateralis and rectus femoris were obtained at midpoints between the greater trochanter and lateral condyle, and that of the rectus femoris was obtained at the midpoint between the anterior superior iliac spine and the proximal border of the patella. During the measurement, the probe was positioned perpendicular to the muscle's longitudinal axis to acquire muscle's cross-sectional image. Sufficient gel was used to ensure proper contact and minimal pressure was applied to the skin to prevent compression of the measured tissue. To ensure the accuracy of the muscle echo intensity (EI) measurements, the ultrasound focus was manually adjusted to the center of the

superficial muscles (Fukumoto et al. 2022).

The muscle thickness (MT) and EI were measured using ImageJ software (version 1.53e, NIH, Bethesda, MD). MT was defined as the vertical distance from the superficial to deep fascia (or femur) at the thickest part of the muscle. EI was quantified as the average pixel intensity (256-scale arbitrary units) within a defined region of interest (ROI). For the vastus lateralis and rectus femoris, a rectangular ROI as large as possible was selected, excluding bone and surrounding fascia. Quadriceps femoris (QF) MT and EI were calculated as follows (Akima et al. 2017): $QFMT = \text{vastus lateralis MT} + \text{rectus femoris MT} + [(\text{vastus intermedius MT beneath the vastus lateralis} + \text{vastus intermedius MT beneath the rectus femoris}) / 2]$, $QFEI = (\text{vastus lateralis EI} + \text{rectus femoris EI}) / 2$.

Knee extension strength testing

The participants were seated upright on a dynamometer (Isoforce GT-330; OG GIKEN Co., Okayama, Japan) with the right knee flexed at 60°. A force sensor was attached 0.26 m distal to the knee joint. After 2–3 practice trials to familiarize participants with the knee extension isometric strength test, maximal isometric muscle strength was measured. Participants were encouraged to extend the knee joint as much as possible and maintain it for 3 s. Two trials were performed with a 30-s rest interval between trials. Knee extension torque (Nm) was calculated as the product of exerted force (N) and lever arm length (0.26 m). The higher value of the two trials was used as the representative knee extension strength for further analysis (Fukumoto et al. 2012).

Physical activity assessment

The participants were provided with a pedometer (EX-500; YAMASA, Tokyo, Japan) after

receiving instructions on how to use it. The participants were instructed to wear the device securely at the waist at all times, except during bathing and sleeping, and to record daily step counts in a self-check sheet. Formal data collection commenced the day after laboratory measurements and continued for 2 weeks. Upon completion of the measurement period, the participants returned the pedometer and self-check sheet to the laboratory via mail. Returned devices and records were examined, and the average daily step count was calculated, excluding days when the device was not worn as instructed. This value was used as the physical activity index.

Statistical analyses

The distribution of variables was examined using histogram features, the Kolmogorov–Smirnov test, and Q-Q plots. All values are presented as means (standard deviations) and counts (percentages) of categorical variables.

Spearman’s correlation analysis was conducted to determine the relationships between blood biomarkers and muscle properties, muscle strength, and physical activity. Additionally, partial correlation coefficients (PCC) were estimated to examine the relationships among these variables while controlling for age and sex (Su et al. 2023).

Mediation analysis was conducted to explore whether the association between blood biomarkers and muscle strength was mediated by muscle properties. Blood biomarkers were used as the independent variable (X), muscle properties as the mediation variable (M), and muscle strength as the dependent variable (Y), whereas sex and age (Model 1) or sex, age, and physical activity (Model 2) were used as covariates. Before the mediation analysis, regression analysis was performed to test the effectiveness of path C (blood biomarker → muscle strength),

path A (blood biomarker → muscle properties), and path B (muscle properties → muscle strength). The mediating effect of the intermediary variable (M) on the relationship between the independent (X) and dependent variables (Y) was then investigated using the 95% confidence interval obtained through the bootstrap method. Indirect effects were considered significant if zero was not included in the bootstrap 95% confidence intervals (CI). We report the results of bootstrapping procedures with resampling of 5000 bootstrap replicates (95% CI). Statistical analysis software (SPSS version 22.0; IBM Japan, Inc., Tokyo, Japan) was used to analyze the data. For the mediation analysis, an SPSS macro (PROCESS version 3.0) developed by Hayes was used to analyze media effects (Hayes 2009). Statistical significance was defined as $p < 0.05$.

Results

A total of 94 participants were initially enrolled in this study; however, nine participants were excluded from the analysis owing to incomplete data. Statistical analyses were performed on 85 participants (39 males; mean age, 75.3 ± 6.7 years). The participants' characteristics are listed in **Table 1**.

The correlation analysis showed that RBC count was positively correlated with QFMT ($\rho = 0.366$, $p = 0.001$) and knee extension strength ($\rho = 0.392$, $p < 0.001$), and negatively correlated with QFEI ($\rho = -0.244$, $p = 0.024$). Hb levels demonstrated similar correlations with QFMT ($\rho = 0.442$, $p < 0.001$), knee extension strength ($\rho = 0.546$, $p < 0.001$), and QFEI ($\rho = -0.406$, $p < 0.001$). Hb levels also showed a significant correlation with physical activity ($\rho = 0.216$, $p = 0.047$). However, no significant correlations were found among other blood biomarkers,

muscle properties, or muscle strength (**Figure 1**).

After adjusting for age and sex (**Table 2**), the RBC count and Hb levels remained correlated with QFMT (RBC: $PCC = 0.320$, $p = 0.004$; Hb: $PCC = 0.253$, $p = 0.023$) and MVC (RBC: $PCC = 0.306$, $p = 0.006$; Hb: $PCC = 0.275$, $p = 0.013$), but not with QFEI (RBC: $PCC = -0.058$, $p = 0.61$; Hb: $PCC = -0.098$, $p = 0.38$) was no longer significant. Furthermore, the adjusted analysis revealed no significant correlation between Hb levels and physical activity.

Since the relationship between RBC count and Hb levels with QFMT and knee extension strength remained significant after adjustment, the pathway RBC count/Hb levels $\rightarrow$ QFMT $\rightarrow$ knee extension strength was further analyzed. We confirmed that RBC count was related to knee extension strength, RBC count was related to QFMT, and QFMT was related to knee extension strength (**Figure 2A**). Bootstrap analysis indicated that the total effect of RBC count on knee extension strength was significant (Model 1 total effect (95%CI) = 0.225 (0.063, 0.389); Model 2 total effect (95%CI) = 0.225 (0.067, 0.383)), with the direct effect not significant (Model 1 direct effect (95%CI) = 0.153 (-0.007, 0.314); Model 2 direct effect (95%CI) = 0.15 (-0.067, 0.383)), but the indirect effect was significant (Model 1 indirect effect (95%CI) = 0.07 (0.003, 0.148); Model 2 indirect effect (95%CI) = 0.08 (0.002, 0.151)), regardless of whether physical activity was controlled (**Table 3**).

Similarly, Hb levels were significantly correlated with knee extension strength; Hb levels were also related to QFMT, and QFMT was related to knee extension strength (**Figure 2B**). In the subsequent bootstrap mediation analysis, the total effect of Hb level on knee extension strength was significant (Model 1 total effect (95%CI) = 7.966 (1.629, 14.303); Model 2 total effect (95%CI) = 7.613 (1.433, 13.793)), among which the direct effect was not significant (Model 1

direct effect (95%CI) = 5.551 (-0.583, 11.685); Model 2 direct effect (95%CI) = 5.032 (-0.878, 10.942)), but the indirect effect was significant (Model 1 indirect effect (95%CI) = 2.415 (0.061, 5.324); Model 2 indirect effect (95%CI) = 2.581 (0.051, 5.415)), regardless of whether physical activity was controlled (**Table 3**).

Discussion

This study investigated the relationship among RBC count, Hb level, muscle properties, and muscle strength in community-dwelling older adults. The results revealed that low RBC count and Hb levels were significantly associated with reduced muscle mass and strength. Specifically, these hematological factors were linked to low muscle strength through a decline in muscle mass, and the relationships were independent of physical activity levels. By integrating these variables within a single cohort and applying objective laboratory-based assessments, this study provides a more refined understanding of their interrelations in a relatively healthy older population. These insights may help clarify the physiological pathways underlying muscle degeneration and functional decline, which are critical for the prevention and management of muscle deterioration.

In this study, reductions in RBC count and Hb level were associated with the deterioration of muscle properties and strength. This finding is partially inconsistent with a previous investigation that examined the relationship between Hb levels along with triceps surae muscle properties and plantar flexion strength in community-dwelling older adults, which reported no association between Hb levels and plantar flexion strength (Cesari et al. 2004). This discrepancy may be attributable to differences in target joints and measurement tools.

Compared with the triceps surae, the quadriceps femoris is the largest muscle group in the human body and may be more susceptible to declines in muscle mass, quality, and strength. Previous studies on aging have indicated that the quadriceps femoris is more vulnerable than the triceps surae to such declines (Fuchs et al. 2023; Ikezoe et al. 2011). Given these age-related differences, reductions in knee extension strength may be more readily detectable and sufficient to reveal associations with hematological parameters such as RBC count and Hb level. In addition, Cesari et al. (2004) employed a hand-held dynamometer, which is more prone to measurement variability and compensatory movements, whereas our fixed dynamometer likely yielded more accurate results. These methodological and physiological differences may partly explain the findings of Hammer et al. (2024), which demonstrated that Hb levels were associated with handgrip strength only in community-dwelling women under 80 years old. Compared with upper limb muscles, which account for approximately 25% of total skeletal muscle mass, lower limb muscles comprise about 50% (Janssen et al. 2000), and may therefore be more sensitive to changes in Hb levels. Furthermore, reduced inter-individual variability in handgrip strength among the oldest adults may limit the ability to detect subtle associations (Tomkinson et al. 2020). Overall, our findings in the quadriceps femoris are consistent with those observed in patient populations, suggesting that such associations may also be present in community-dwelling individuals. Nevertheless, the underlying causes of inconsistent results in community-based studies warrant further investigation.

In the present study, after adjusting for age and sex, the relationship between RBC count, Hb level, and echo intensity was no longer significant. The echo intensity was highly correlated with and strongly influenced by age (Kobayashi et al. 2023). Because RBC count and Hb levels

also decrease with age (Su et al. 2023), it is possible that RBC count and Hb levels are not significantly associated with echo intensity after adjusting for age. In contrast, the RBC count and Hb levels remained significantly positively associated with muscle thickness and strength, even after adjusting for age and sex. This suggests that, regardless of age or sex, lower RBC counts and Hb levels are associated with frailty (Mailliez et al. 2020) and with the hallmarks of sarcopenia, including reductions in muscle mass and strength (Cruz-Jentoft and Sayer 2019; Cruz-Jentoft et al. 2019), underscoring the importance of routine blood monitoring to facilitate early detection and intervention in community-dwelling older adults.

Regardless of physical activity adjustment, RBC count and Hb level were related to muscle strength, which was mediated by muscle mass. Previous studies have proposed the hypothesis that anemia or lower Hb levels are associated with reduced physical activity, and that a long-term sedentary lifestyle can lead to decreases in muscle mass and strength (Cecchi et al. 2017; Pires Corona et al. 2015; Santos et al. 2019). In present study, participants' physical activity ranged from 4670.0–9364.0 steps/day, which is consistent with the 3500.0–11000.0 steps/day in community-dwelling older people reported in previous studies (Freire et al. 2022; Takayanagi et al. 2021; Yuki et al. 2019). In this population, we did not observe any effect of physical activity on the relationship among RBC count, Hb levels, muscle mass, and strength. Therefore, our findings suggest that RBC count and Hb levels are associated with muscle mass and strength for reasons other than physical activity levels in community-dwelling older people.

The mediation analysis demonstrated that RBC count and Hb levels were associated with muscle strength indirectly through muscle mass, while the direct path from Hb to strength was not statistically significant. Although the direct effects did not reach statistical significance

($p=0.058-0.094$), they approached significance and may become meaningful in studies with larger sample sizes capable of detecting small-to-moderate effects. These findings suggest that reductions in RBC count and Hb level may contribute to muscle weakness primarily through decreases in muscle mass, although a potential direct pathway cannot be excluded. Given the physiological roles of RBC count and Hb in oxygen transport and muscle metabolism (Crispin 2020; Lundgren et al. 2021; Vinke et al. 2023), further longitudinal studies are needed to clarify the mechanisms linking hematological factors to muscle properties and muscle strength. Our findings indicate that, in addition to muscle-targeted interventions, maintaining adequate hematological health may be essential for preserving muscle mass and preventing functional decline in older adults.

This study has several limitations that warrant discussion. First, we focused on the relationship between the muscle properties of the quadriceps femoris and the RBC count and Hb levels, and it is unclear whether our findings are applicable to other muscles. Second, the sample size for the mediation analysis was relatively small. Although we adopted a bootstrap method, which helped minimize the risk of type I error and allowed for reliable estimation even with a small sample size (Hayes 2009; Preacher and Hayes 2004), our sample did not meet the recommended minimum of 148 participants (Fritz and Mackinnon 2007). Nevertheless, the significant indirect effect observed provides preliminary support for the proposed mediation model, in which RBC count and Hb levels are associated with muscle strength through muscle mass. However, the small sample size may have reduced our power to detect a direct association. Future studies with larger cohorts are needed to confirm these findings. Third, all indices in this study were measured at the same time point, which limited our ability to

determine causal relationships. Therefore, prospective longitudinal and interventional studies are required to confirm these findings.

Conclusion

Our results revealed that low RBC counts and Hb levels were associated with reduced muscle mass and weakness among community-dwelling older adults. Furthermore, the relationship between low RBC count, Hb levels, and muscle weakness may be mediated by a decrease in muscle mass.

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Competing interests statement

The authors declare there are no competing interests.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics approval statement

The experimental protocols were approved by the Ethics Committee of Kyoto University (ethics approval number: R1746)

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459

Table legends

Table 1. Characteristics of participants.

Variable	Total	Female	Male
	n=85	n=46	n=39
Age, years	75.3±6.7	74.2±6.9	76.6±6.2
gender, male, n (%)	39 (45.9%)	-	-
Height (cm)	158.5±8.9	152.2±5.2	166.2±6.0
Weight (kg)	54.0±8.7	48.7±5.4	60.3±7.6
BMI (kg/m ²)	21.4±2.5	21.0±2.4	21.9±2.6
RBC count (10 ⁶ /μL)	431.4±45.7	418.5±39.1	447.4±50.2
WBC count (10 ³ /μL)	50.0±11.0	49.1±12.8	51.2±8.3
PLT count (10 ³ /μL)	21.6±5.0	22.1±5.1	20.9±4.9
Hb levels (g/dL)	13.4±1.4	12.7±1.1	14.3±1.3
Anemia, n (%)	14 (16.5%)	9 (19.6%)	5 (12.8%)
QFMT (cm)	5.1±1.0	4.8±0.8	5.5±0.9
QFEI (a.u.)	85.5±12.8	90.8±11.9	79.2±11.0
Knee extension strength (Nm)	119.2±30.0	98.0±27.1	144.2±38.4
Physical activity (steps/day)	7566.8±3537.2	7024.3±2885.0	8228.4± 4139.9

Parameter data are represented as the mean ± standard deviation, and categorical variables are presented as counts (percentage).

BMI: Body mass index, RBC: Red blood cell, WBC: White blood cell, PLT: Platelet, Hb: Hemoglobin, QFMT: Quadriceps femoris muscle thickness, QFEI: Quadriceps femoris echo intensity.

Table 2. Association between blood biomarkers and muscle properties, muscle strength, and physical activity after adjustment for age and sex.

	RBC count		WBC count		PLT count		Hb levels	
	PCC	p	PCC	p	PCC	p	PCC	p
QFMT	0.320	0.004	0.117	0.298	-0.097	0.390	0.253	0.023
QFEI	-0.058	0.605	0.048	0.671	0.089	0.430	-0.098	0.382
Knee extension strength	0.306	0.006	0.099	0.377	-0.136	0.225	0.275	0.013
Physical Activity	-0.007	0.948	0.019	0.870	-0.077	0.495	0.046	0.684

Values with statistically significant differences ($p < 0.05$) are presented in **bold**.

RBC: Red blood cell, WBC: White blood cell, PLT: Platelet, Hb: Hemoglobin, PCC: Partial correlation coefficient, QFMT: Quadriceps femoris muscle thickness, QFEI: Quadriceps femoris echo intensity.

Table 3. Total, direct, and indirect effects of blood biomarkers on muscle strength mediated by muscle properties.

	Total effect		Direct effect		Indirect effect
	Effect (bootstrap 95% CI)	p	Effect (bootstrap 95% CI)	p	Effect (bootstrap 95% CI)
RBC count → QFMT → Knee extension strength					
Model 1	0.225 (0.063, 0.389)	0.007	0.153 (-0.007, 0.314)	0.061	0.072 (0.003, 0.148)
Model 2	0.225 (0.067, 0.383)	0.006	0.149 (-0.005, 0.303)	0.058	0.076 (0.002, 0.151)
Hb levels → QFMT → knee extension strength					
Model 1	7.966 (1.629, 14.303)	0.014	5.551 (-0.583, 11.685)	0.076	2.415 (0.061, 5.324)
Model 2	7.613 (1.433, 13.793)	0.016	5.032 (-0.878, 10.942)	0.094	2.581 (0.051, 5.415)

Values with statistically significant differences ($p < 0.05$) are presented in **bold**.

Indirect effects were considered significant if zero was not included in the bootstrap 95% confidence intervals (CI).

Model 1: Mediation model controlling for age and sex,

Model 2: Mediation model controlling for age, sex, and physical activity.

RBC: Red blood cell, QFMT: Quadriceps femoris muscle thickness, Hb: Hemoglobin.

Figure legends

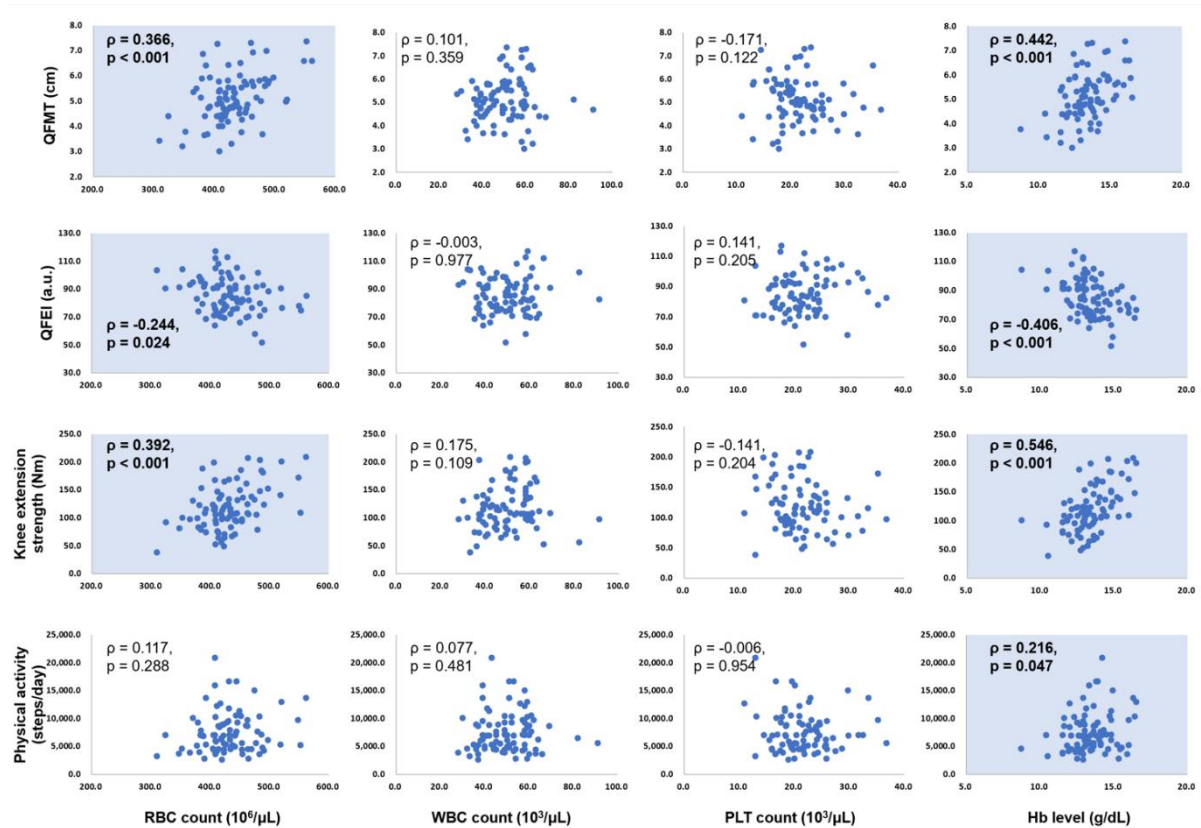


Figure 1. Associations between blood biomarkers and muscle properties, muscle strength, and physical activity.

Values with statistically significant differences ($p < 0.05$) are presented in **bold**.

RBC: Red blood cell, WBC: White blood cell, PLT: Platelet, Hb: Hemoglobin, QFMT: Quadriceps femoris muscle thickness, QFEI: Quadriceps femoris echo intensity.

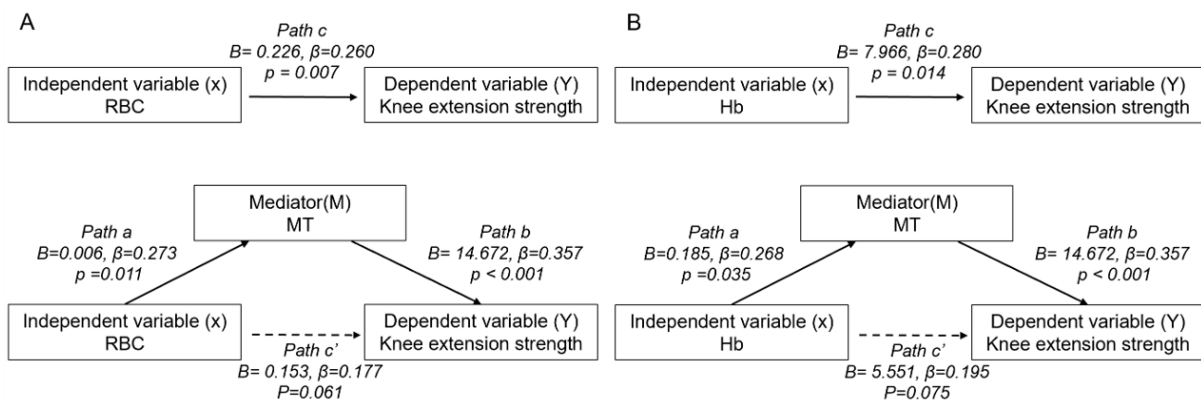


Figure 2. Association between blood biomarkers, muscle properties and muscle strength,
controlling for age and sex.

A. Results of the association between RBC count and muscle strength with MT as mediators.

B. Results of the association between Hb levels and muscle strength with MT as mediators.

The scatter plot illustrating *path b* is provided in the **supplementary materials**.

RBC: Red blood cell, MT: Muscle thickness, Hb: Hemoglobin.